

SYSTEMS AND METHODS FOR USING SELECTABLE FRAME DURATIONS IN A WIRELESS COMMUNICATION SYSTEM

Claim of Priority under 35 U.S.C. §119

[0001] The present application is a non-provisional application claiming priority to provisional application Serial No. 60/448,269, entitled "REVERSE LINK DATA COMMUNICATION", filed on February 18, 2003; U.S. provisional application serial number 60/452,790, entitled "METHOD AND APPARATUS FOR A REVERSE LINK COMMUNICATION IN A COMMUNICATION SYSTEM", filed on March 6, 2003; and U.S. provisional application serial number 60/470,770, entitled "OUTER-LOOP POWER CONTROL FOR REL. D", filed on May 14, 2003.

BACKGROUND

Field of the invention

[0002] The invention relates generally to the field of telecommunications, and more particularly to mechanisms for controlling data transmission parameters for wireless communications channels based upon prevailing transmission characteristics of the channels.

Related art

[0003] Wireless communication technologies are rapidly advancing, and wireless communication systems are utilized to provide a larger and larger portion of the communications capacity that is currently available to users. This is true despite the additional technological impediments that are faced in implementing a wireless communication system, as compared to a wireline system. For instance, wireless communication systems must deal with issues relating to power control between a base station and its mobile stations in order to maximize the performance of the system, whereas a wireline system does not.

[0004] One type of wireless communication system comprises a cellular CDMA (code division multiple access) system which is configured to support voice and data communications. This system may have multiple base stations which communicate via wireless channels with multiple mobile stations. (The base stations are also typically coupled via wireline networks to various other systems, such as a public switched telephone network.) Each base station communicates with a set of mobile stations that are within a sector corresponding to the base station.

[0005] It is typically a goal of a wireless communication system to optimize the performance of the system by maximizing the data throughput of the system. This data throughput may include contributions from each of the mobile stations with which the base station communicates. Because the base station typically communicates with multiple mobile stations, the system cannot simply allow communications between the base station and one of the mobile stations to be optimized at the expense of communications with the other mobile stations. On the other hand, the system cannot allow communications with all of the mobile stations to use the highest power levels, data rates and other transmission parameters that are physically possible because they would likely generate so much interference that little, if any, of the data would actually be successfully transmitted. It is therefore necessary for the system to implement controls on the communications with the different mobile stations in order to provide an acceptable level of service to each of them.

[0006] A complicating factor in the control of the communications between a base station and various mobile stations is that the mobile stations may be in communication with more than one base station. While a mobile station which is located in close proximity to a first base station generates interference that primarily affects the mobile stations in the same sector, mobile stations that are farther from the base station may generate interference that significantly affects mobile stations in other sectors. While a single base station can handle the first situation relatively easily, it has no knowledge of mobile stations in other sectors, and may therefore require complicated backhaul signaling to handle the second situation. It would therefore be desirable to provide a means to handle the second situation which increases system performance in relation to all of the base stations and corresponding sectors.

SUMMARY OF THE INVENTION

[0007] One or more of the problems outlined above may be solved by the various embodiments of the invention. Broadly speaking, the invention comprises systems and methods for setting parameters for transmissions of data from a mobile station to a base station in a wireless communications system. One embodiment of the present invention comprises a method for determining when conditions are appropriate for a mobile station to enter or leave a soft handoff state, and setting transmission parameters for the mobile station based upon whether or not the mobile station is in soft handoff.

[0008] One embodiment of the present invention comprises a method implemented in a wireless communication system having one or more base stations connected to a network and one or more mobile stations that are in communication with the base stations. The method includes the steps of detecting a mobile station entering or leaving soft handoff and modifying a transmission parameter for the mobile station in response to detecting the mobile station entering or leaving soft handoff. In one embodiment, the transmission parameter comprises a frame size, wherein if the mobile station is in soft handoff, the frame size is set to a first size (e.g., 10 milliseconds) and wherein if the mobile station is not in soft handoff, the frame size is set to a second size (e.g., 2 milliseconds). In one embodiment, the mobile station measures pilot signal strengths for each of one or more base stations and periodically transmits pilot strength measurement messages (PSMMs) to the network via the one of the base stations. The network determines whether to direct the mobile station to enter or leave soft handoff based upon the received PSMMs and, if necessary, sends a handoff direction message (HDM) to the base station, which transmits the HDM to the mobile station. In response to receiving the HDM, the mobile station enters or leaves soft handoff as directed by the network and also sets the transmission parameter (e.g., frame size) accordingly. The mobile station then transmits a handoff completion message the network after entering or leaving soft handoff and setting the transmission parameter.

[0009] An alternative embodiment of the present invention comprises a wireless communication system. The system includes a network, a base station and a mobile station, wherein the mobile station is configured to set a transmission parameter according to whether or not the mobile station is in soft handoff. In one embodiment, the transmission parameter comprises frame size, and the mobile station is configured to

set the frame size to a first, greater value if the mobile station is in soft handoff, and to set the frame size to a second, smaller value if the mobile station is not in soft handoff. In one embodiment, the mobile station is configured to measure a pilot signal strength for each of one or more base stations and to periodically transmit PSMMs to the network. The network in this embodiment is configured to identify a change in a number of base stations in the active set (the set of base stations with which the mobile station communicates) for the mobile station (based on the PSMMs) and to direct the mobile station to enter or leave soft handoff based on the change in the number of base stations in the active set. The network then sends a handoff direction message (HDM) to the mobile station. The mobile station is configured to enter or leave soft handoff, to modify the transmission parameter in response to receiving the HDM and then to transmit a handoff completion message to the network.

[0010] Numerous additional embodiments are also possible.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Various aspects and features of the invention are disclosed by the following detailed description and the references to the accompanying drawings, wherein:

[0012] FIGURE 1 is a diagram illustrating an exemplary arrangement of base stations, the respective sectors served by the base stations, and mobile stations in a wireless telecommunications system in accordance with one embodiment;

[0013] FIGURE 2 is a diagram illustrating the structure of an exemplary wireless communications system in accordance with one embodiment;

[0014] FIGURE 3 is a functional block diagram illustrating the basic structural components of a wireless transceiver system in accordance with one embodiment;

[0015] FIGURE 4 is a diagram illustrating changes in the strengths of pilot signals from two different base stations, as measured by a single mobile station in accordance with one embodiment;

[0016] FIGURE 5 is a flow diagram illustrating a method implemented in a mobile station in accordance with one embodiment; and

[0017] FIGURE 6 is a flow diagram illustrating a method implemented in a base station in accordance with one embodiment.

[0018] While the invention is subject to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and the

accompanying detailed description. It should be understood, however, that the drawings and detailed description are not intended to limit the invention to the particular embodiments which are described.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0019] One or more embodiments of the invention are described below. It should be noted that these and any other embodiments described below are exemplary and are intended to be illustrative of the invention rather than limiting.

[0020] As described herein, various embodiments of the invention comprise systems and methods for setting parameters for transmissions of data from a mobile station to a base station in a wireless communications system. One embodiment of the present invention comprises a method for determining when conditions are appropriate for a mobile station to enter a soft handoff state, and setting transmission parameters for the mobile station based upon whether or not the mobile station is in soft handoff.

[0021] In one embodiment, the method is implemented in a wireless telecommunications system having a plurality of base stations and a plurality of mobile stations. Each of the mobile stations can move throughout the geographic area within which the base stations provide communication service. As each mobile station moves within this area, the quality of each of the communication links between the mobile station and various ones of the base stations may change. Typically, when a mobile station is relatively close to a base station, the quality of the corresponding communication link is good, and transmission parameters for the communication link may be set to support a high data transmission rate (e.g., a shorter frame period may be used). As the mobile station moves toward the edge of the sector which is served by the base station, the quality of the communication link is usually degraded, and it is typically necessary to set the transmission parameters for the communication link to support a reduced data rate (in order to provide an acceptable error rate).

[0022] One of the problems with trying to adjust the transmission parameters of the communication link according to the quality of the link is that it is typically necessary to perform a significant amount of signaling between the mobile station and the base station simply to have enough information to appropriately adjust the transmission parameters. This signaling represents overhead that reduces the bandwidth available for

data transmissions. The signaling also generates interference that may reduce the throughput of other mobile stations. The various embodiments of the present invention may eliminate a substantial amount of this communication overhead by setting transmission parameters based upon conditions that are known to apply. These conditions are known from currently used overhead information.

[0023] In one embodiment, it is assumed that a mobile station which is in soft handoff is near the edge of the sector being served by the base station. It is therefore also assumed that the quality of the communication link between the mobile station and the base station is not sufficient to support a high data rate. Consequently, whenever the mobile station is in soft handoff (i.e., the mobile station is communicating with more than one base station), the frame size (i.e., the amount of time over which a frame of data is transmitted) is set to the larger of two frame sizes. This larger frame size corresponds to a lower data rate, which requires less power to achieve an acceptable error rate. When the mobile station is not in soft handoff, the frame size is set to the smaller of these sizes. In one embodiment, frame sizes of either 10 milliseconds (in soft handoff) or 2 milliseconds (not in soft handoff) are used.

[0024] In one embodiment, the frame size is set as part of the handoff direction messaging process. In this embodiment, a mobile station communicates primarily with a single base station. The mobile station is configured to periodically determine the strength of pilot signals that are received, not only from the primary base station, but from each base station from which a pilot signal is received. The mobile station is also configured to periodically transmit pilot strength measurement messages (PSMMs) to the primary base station, indicating the strength of the pilot signals from each base station. The pilot strength information is forwarded to a switching station or other network to which all of the base stations are connected. Based upon the pilot strength information, it is determined whether or not the mobile station should be in soft handoff between multiple base stations. Messages are then forwarded to the mobile station if necessary to direct the mobile station to enter or leave a state in which the mobile station is in soft handoff. When the mobile station receives one of these messages, the mobile station not only enters or leaves a soft handoff state, but also automatically sets the transmission parameters (e.g., the frame size) to the appropriate values for the current state of the mobile station.

[0025] The various embodiments of the present invention may provide a number of advantages over the prior art. For example, because the embodiment described above utilizes a soft handoff mechanism that is already present, no additional signaling is necessary to provide the information needed by the mobile station to determine whether the frame size should be set to the larger or smaller of the two possible values. Still other advantages will be apparent to those of skill in the art of the invention.

[0026] Referring to FIGURE 1, a diagram illustrating a plurality of base stations and a plurality of mobile stations in a wireless telecommunications system in accordance with one embodiment is shown. FIGURE 1 depicts three of the base stations 12 in the system. Many more base stations may also be included in the system. Each base station 12 has an associated sector 14, which is simply a coverage area wherein mobile stations in the area can communicate with the base station. (While the sectors in the figure are distinctly delineated by dotted lines, the sectors do not have distinct boundaries, but instead have more graduated boundaries that are determined by the strength of the signals communicated between the corresponding base station and the mobile stations in the sector.) A number of mobile stations 16 are shown scattered throughout the coverage area of the combined sectors.

[0027] It should be noted that, for purposes of clarity, not all of the base stations, sectors, and mobile stations in the figure are identified by corresponding reference numbers. Where each of these elements of the network is referred to herein by the corresponding reference number without a lowercase letter (e.g., "12"), the reference is applicable to any of the identical elements. Where the elements are referred to by the corresponding reference number followed by a lowercase letter (e.g., "12a"), the reference is applicable to the particular element identified in the figure.

[0028] Referring to FIGURE 2, a diagram illustrating the structure of an exemplary wireless communications system is shown. As depicted in this figure, system 200 comprises a base station 210 that is configured to communicate with a plurality of mobile stations 220. Mobile stations 220 may, for example, be cellular telephones, personal information managers (PIMs or PDA), or the like that are configured for wireless communication. It should be noted that these devices need not actually be "mobile," but may simply communicate with base station 210 via a wireless link. Base station 210 transmits data to mobile stations 220 via corresponding forward link (FL)

channels, while mobile stations 220 transmit data to base station 210 via corresponding reverse link (RL) channels.

[0029] It should be noted that, for the purposes of this disclosure, identical items in the figures may be indicated by identical reference numerals followed by a lowercase letter, e.g., 220a, 220b, and so on. The items may be collectively referred to herein simply by the reference numeral.

[0030] Base station 210 is also coupled to a switching station 230 via a wireline link. The link to switching station 230 allows base station 210 to communicate with various other system components, such as a data server 240, a public switched telephone network 250, or the Internet 260. It should be noted that the mobile stations and system components in this figure are exemplary and other systems may comprise other types and other combinations of devices.

[0031] While, in practice, the specific designs of base station 210 and mobile stations 220 may vary significantly, each serves as a wireless transceiver for communicating over the forward and reverse links. Base station 210 and mobile stations 220 therefore have the same general structure. This structure is illustrated in FIGURE 3.

[0032] Referring to FIGURE 3, a functional block diagram illustrating the basic structural components of a wireless transceiver system in accordance with one embodiment is shown. As depicted in this figure, the system comprises a transmit subsystem 322 and a receive subsystem 324, each of which is coupled to an antenna 326. Transmit subsystem 322 and receive subsystem 324 may be collectively referred to as a transceiver subsystem. Transmit subsystem 322 and receive subsystem 324 access the forward and reverse links through antenna 326. Transmit subsystem 322 and receive subsystem 324 are also coupled to processor 328, which is configured to control transmit and receive subsystems 322 and 324. Memory 330 is coupled to processor 328 to provide working space and local storage for the processor. A data source 332 is coupled to processor 328 to provide data for transmission by the system. Data source 332 may, for example, comprise a microphone or an input from a network device. The data is processed by processor 328 and then forwarded to transmit subsystem 322, which transmits the data via antenna 326. Data received by receive subsystem 324 through antenna 326 is forwarded to processor 328 for processing and then to data output 334 for presentation to a user. Data output 334 may comprise such devices as a speaker, a visual display, or an output to a network device.

- [0033] Considering the structure of FIGURE 3 as implemented in a mobile station, the components of the system can be viewed as a transceiver subsystem coupled to a processing subsystem, where the transceiver subsystem is responsible for receiving and transmitting data over wireless channel and the processing subsystem is responsible for preparing and providing data to the transceiver subsystem for transmission and receiving and processing data that it gets from the transceiver subsystem. The transceiver subsystem could be considered to include transmit subsystem 322, receive subsystem 324 and antenna 326. The processing subsystem could be considered to include processor 328, memory 330, data source 332 and data output 334.
- [0034] The transceiver subsystems of the base station and mobile station enable them to communicate via a wireless link. This wireless link may include a number of forward-link channels which are used to transmit data from the base station to the mobile station, as well as a number of reverse-link channels which are used to transmit data from the mobile station to the base station.
- [0035] The quality of the wireless communication link between the base station and a mobile station may depend upon a variety of factors, many of which are constantly changing. For example, the quality of the link may vary with atmospheric conditions, geographic features, obstacles, the distance between the base station and the mobile station, and so on. Each of these factors may cause the quality of the communication link to change as the position of the mobile station changes, sometimes improving the quality of the link, and sometimes degrading it. It is typically necessary for the mobile station to take into account the resulting communication link quality in determining the parameters that will be used to transmit data from the mobile station to the base station in order to achieve an acceptable error rate for data transmitted over the link.
- [0036] The factors mentioned above and their effects on the communication link are generally very difficult to predict or anticipate. It is therefore typically necessary to directly determine the quality of the communication link and then set the transmission parameters of the mobile station according to the quality of the link. This may require some overhead signaling back and forth between the mobile station and the base station. Thus, some of the resources of the system (e.g. mobile station power and communication link bandwidth) must be used for overhead rather than data transmissions.

[0037] While it is generally difficult, if not impossible, to anticipate changes in the factors that affect communication link quality and to set the transmission parameters accordingly, some generalizations can be made with respect to some of the factors. For example, with respect to the distance between the base station and the mobile station, it can be assumed that as the distance between the base station and the mobile station increases, the quality of the communication link will decrease (since the received energy of the transmitted signal typically decreases with distance). It may therefore be reasonable to assume that, when the mobile station is near the base station, the communication link will be capable of supporting higher data throughput than when the mobile station is far from the base station. As a practical matter, this means that the mobile station can use a shorter frame length (duration) or higher data rate to transmit data to the base station. When the mobile station is near the base station, it is also less likely that transmitting data at a higher rate (and at a corresponding higher power level) will generate interference that will significantly affect communications between mobile stations and other base stations. When the mobile station is far from the base station, on the other hand, it may be necessary to use a larger frame in order to achieve an acceptable error rate and to minimize the interference with mobile stations in other sectors.

[0038] The area within the sector of the base station can therefore be divided into regions, where in a "near" region, the communication link is capable of supporting a higher level of data throughput and, in a "far" region, the communication link is capable of supporting a lower level of data throughput. Consequently, when the mobile station is in the "near" region, the parameters for transmission data from the mobile station to the base station can be set in accordance with the higher level of data throughput. When the mobile station is in the "far" region, the transmission parameters can be set in accordance with the lower level of data throughput.

[0039] For example, in one embodiment, a mobile station may use either a 10 millisecond frame size, or a 2 millisecond frame size. When the 10 millisecond frame size is used, a frame of data is transmitted over the 10 millisecond duration of the frame. When the 2 millisecond frame size is used, the same amount of data is transmitted over a 2 millisecond duration. The data transmitted in the 2 millisecond frame must therefore be transmitted at a data rate which is five times the data rate used with the 10 millisecond frame. This higher data rate corresponds to a higher power level.

Therefore, in this embodiment, the mobile station is configured to use the 2 millisecond frame size when the mobile station is in the "near" region of the sector, and to use the 10 millisecond frame size when the mobile station is in the "far" region.

[0040] In a preferred embodiment, the selection of an appropriate frame size for data transmissions from the mobile station is performed in conjunction with the process of performing soft handoff. As indicated above, mobile stations may be in communication with more than a single base station. Although the mobile station communicates primarily with a first one of the base stations, the mobile station may begin communicating with (e.g., listening to) other base stations in preparation for the possibility that the quality of the communication link to the first base station may degrade to the point that the mobile station should communicate primarily with a different one of the base stations. When the mobile station is communicating with multiple base stations, the mobile station is in soft handoff.

[0041] This may be illustrated by the diagram of FIGURE 4. This figure illustrates changes in the strengths of pilot signals from two different base stations, as measured by a single mobile station. In this figure, curve 410 represents the strength of the pilot signal from a first base station as a function of time. Curve 420 represents the strength of the pilot signal from a second base station. Line 430 indicates a threshold pilot strength. When the pilot strength of a base station is greater than the threshold level, the communication link to that base station is strong enough for the base station to become part of the active set (the set of base stations with which the mobile station can communicate). Thus, before time t_0 , only one of the base stations (the first base station) is above the threshold. The strength of the pilot signal from the second base station is below the threshold during this time, but is increasing. At time t_0 , the pilot signal of the second base station reaches the threshold level. The mobile station could therefore be in soft handoff with the two base stations after time t_0 , until one of the base stations' pilot strengths drops below the threshold level.

[0042] It should be noted that, while the example above describes the mobile station's interaction with two base stations, there may be many more base stations involved. The mobile station monitors the pilot signal strengths of each of the base stations from which a pilot signal is received. The base stations for which the pilot signal strengths are above the threshold level typically comprise the active set for the mobile station.

[0043] The significance of the soft handoff in relation to various embodiments of the present invention is that, generally speaking, soft handoff occurs when a mobile station is located in the "far" region of the sector which is served by the first base station. In other words, because the sectors served by the different base stations overlap at the edges of the sectors away from the respective base stations (see FIGURE 1), a mobile station which is in soft handoff will be near the edge of the sector, which generally coincides with the "far" region of the sector.

[0044] Referring again to FIGURE 1, mobile station 16a is an example of a mobile station which is not in soft handoff. Mobile station 16a is served by base station 12a. Mobile station 16a is sufficiently far from base stations 12b and 12c that the signal strength from each of these base stations would be low and mobile station 16a would not be directed to communicate with either of these base stations. Mobile station 16b, the other hand, is an example of a mobile station which is most likely in soft handoff. While mobile station 16b may still be served primarily by base station 12a, it is sufficiently close to base station 12b that it may be directed to communicate with both of these base stations (i.e., 12a and 12b).

[0045] In one embodiment, the soft handoff mechanism for a mobile station involves monitoring the pilot signals from the various base stations and directing the mobile station to enter or leave a soft handoff state, depending upon the strengths of the various pilot signals. Then, when the mobile station is directed to enter or leave the soft handoff state, the mobile station not only enters or leaves soft handoff, but also sets the parameters for transmissions to the base station based upon whether or not the mobile station is then in soft handoff.

[0046] Referring to FIGURE 5, a flow diagram illustrating a method implemented in a mobile station in accordance with one embodiment of the present invention is shown. As depicted in this figure, the mobile station measures the strengths of the pilot signals received from the various base stations (block 510 and periodically sends pilot strength measurement messages (PSMMs) to the network (block 520). As will be explained in more detail below, the mobile station may receive a handoff direction message (HDM) from the network (block 530). The HDM may direct the mobile station either to enter or soft handoff or leaves soft handoff. The mobile station therefore enters or leaves soft handoff as directed by the HDM (block 540). The mobile station also sets the transmission parameters based upon whether the mobile station is directed by the HDM

to enter or leave soft handoff (block 550). When the mobile station is finished entering or leaving soft handoff and setting the appropriate transmission parameters, a handoff completion message (HCM) is transmitted back to the network (block 560).

[0047] Referring to FIGURE 6, a flow diagram illustrating a method implemented in a base station in accordance with one embodiment of the present invention is shown. As shown in the figure, the network first receives one of the PSMMs (block 610). If the mobile station was previously in soft handoff (block 620), the network then examines the pilot signal strength information in the PSMM and determines whether there is only one base station for which the corresponding pilot signal strength remains above the threshold level (block 630). If there are still multiple base stations for which the corresponding pilot signal strengths are above the threshold, the mobile station should remain in soft handoff, so no action is taken by the network. If there is only one base station for which the corresponding signal strength is above the threshold, the mobile station should no longer be in soft handoff, so the network sends an HDM to the mobile station directing the mobile station to leave soft handoff (block 640).

[0048] If the mobile station was not previously in soft handoff (block 620), the network examines the pilot signal strength information in the PSMM and determines whether there are multiple base stations for which the corresponding pilot signal strengths above the threshold level (block 650). If there is still only one base station for which the corresponding pilot signal strength is above the threshold, the mobile station still should not be in soft handoff, so no action is taken by the network. If there are multiple base stations for which the corresponding pilot signal strengths are above the threshold, the mobile station should be in soft handoff, so the network sends an HDM to the mobile station directing the mobile station to enter soft handoff (block 660).

[0049] It should be noted that the use of a threshold pilot signal strength level as described above for determining whether or not various base stations should be in a mobile station's active set is exemplary. The threshold may be set at a constant level, or it may vary, depending upon the particular circumstances that exist at a particular time. For instance, the threshold may be set at a level that is a certain amount lower than the level of the strongest pilot signal. Alternatively, the threshold may comprise a set of threshold conditions. For example, there may be an absolute threshold, below which no base station may be in the active set, and a variable threshold that may be set at a level

that allows no more than a predetermined number of base stations to be in the active set. Many other variations are also possible.

[0050] The embodiments described above make use of an existing mechanism to set parameters for the transmission of data from a mobile station to a base station. In particular, a soft handoff status is used to set a frame size for transmissions from the mobile station to the base station. The use of this existing mechanism enables the control of the frame size based upon the rough estimation of the mobile station's position (e.g., near the edge of the sector, where soft handoff typically occurs) without adding the overhead of explicitly communicating the position of the mobile station. In other embodiments, it may be possible to use other existing mechanisms and to control other transmission parameters using these mechanisms.

[0051] It should be noted that, in the embodiments described above, method steps can be interchanged without departing from the scope of the invention. The steps of the methods described above may be embodied in hardware, software, firmware or any combination thereof. The method steps may comprise instructions configured to cause a data processor to perform the corresponding method, and the instructions may be embodied in a medium readable by the data processor, such as RAM, ROM, flash memory, EPROM, EEPROM, registers, hard disks, removable disks, CD-ROMs, or any other storage medium known in the art. The storage medium may be integral to the data processor, or it may be external.

[0052] While, in some of the descriptions above, references are made to signals, parameters, and procedures associated with particular standards (e.g., cdma2000, Rel. D), the invention is not limited to embodiments that conform to these standards. It will be appreciated by those of ordinary skill in the art of the invention that the generic descriptions above are applicable to systems and methods that conform to other standards, and that such alternative embodiments are within the scope of the invention.

[0053] It will also be appreciated by those of ordinary skill in the art of the invention that the information and signals described above may be represented using any variety of different technologies and techniques. For example, data, instructions, commands, bits, symbols, chips and various other information and signals may be represented by voltages, currents, electromagnetic waves, magnetic fields, optical fields, or the like.

[0054] Those of ordinary skill in the art of the invention will further appreciate that the various logical or functional blocks, modules, circuits, components, algorithm steps and

the like that are described in connection with the foregoing embodiments may be implemented as hardware, software, firmware, or combinations thereof. Further, each of these logical or functional blocks, etc., may themselves be implemented in a variety of different configurations. For example, one or more of the logical or functional blocks may be implemented or performed with a data processor that may comprise a general-purpose processor, a microprocessor, a microcontroller, a state machine, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic devices, discrete gate or transistor logic, discrete hardware components, or any combination thereof.

[0055] The various aspects and features of the present invention have been described above with regard to specific embodiments. As used herein, the terms 'comprises,' 'comprising,' or any other variations thereof, are intended to be interpreted as non-exclusively including the elements or limitations which follow those terms. Accordingly, a system, method, or other embodiment that comprises a set of elements is not limited to only those elements, and may include other elements not expressly listed or inherent to the claimed embodiment.

[0056] While the present invention has been described with reference to particular embodiments, it should be understood that the embodiments are illustrative and that the scope of the invention is not limited to these embodiments. Many variations, modifications, additions and improvements to the embodiments described above are possible. It is contemplated that these variations, modifications, additions and improvements fall within the scope of the invention as detailed within the following claims.

What is claimed is: